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(71) Applicant *(for all designated States except US)*: KBL PROCESS A/S [NO/NO]; Kokstadveien 26, N-5061 Kokstad (NO).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : LERUM, Atle [NO/NO]; Nipedalen 143, N-5034 Y. Laksevåg (NO).

(74) Agent: REISTAD, Gunnar, O.; Bryns Patentkontor A/S, P.O. Box 9566, Egertorget, N-0128 Oslo 1 (NO).

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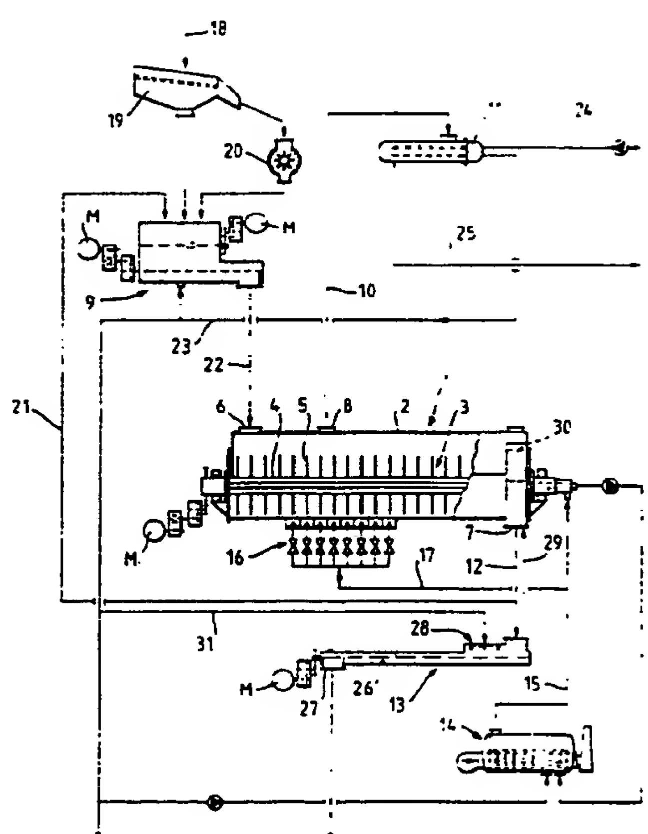
(54) Title: A METHOD IN TREATING SOLID MATERIAL TO REMOVE VAPORIZABLE MATTER FROM IT

(57) Abstract

A method is described in treating solid material to remove vaporizable substances from said material, comprising a thermal separation process, in which the solid material is subjected to heating and steam distillation for evaporation of substances to be separated off, especially to remove hydrocarbons from cuttings, polluted soil, etc. Heating for evaporation comprises heating in a heat exchanger, comprising a casing with a rotatable hollow rotor provided in said casing, and wherein the material is conveyed during indirect heating, from an inlet to an outlet, heating being carried out with a rising temperature profile in the direction of conveyance. Steam is injected directly into the material in a region of lower temperature in the heat exchanger, and the exhaust gas is discharged from the heat exchanger and led to a condenser.



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A method in treating solid material to remove vaporizable matter from it.

The invention relates to a method in treating solid material to remove vaporizable matter from it, comprising a thermal separaration process, in which the solid material is subjected to heating for evaporation of substances to be separated from said material.

Examples to be mentioned of materials for the treatment of which the method was developed, are wastes from drilling mud generally, especially in connection with utilization of oil based drilling mud. Such waste results from drilling operations, i.e. cuttings and after weight reduction of mud after completed drilling. Said waste consists of formation minerals drilled from the well, and attached drilling mud (consisting of oil, water, barite, finely particulate clay, brine and various chemical additives). After weight reduction the material comprises proportionally larger amounts of barite, or another weighting material.

The ratio of solids to liquids of the waste material will vary much dependent on geological conditions at the place where the well is drilled, and dependent on mud processing equipment on the actual installation/drilling vessel.

Empirically, its liquid content is between 15 and 60% by weight.

Water based mud, with special chemicals (polymers, etc) used, is, obviously, also a material for the treatment of which the method may be used. Such mud does not contain "drilling oil", i.e. common paraffins, but for the rest it is a very similar waste.

Another group of materials of interest comprises polluted

sand, soil, seaweed, etc. in connection with shipwrecking, and discharges of oil/chemicals.

The method may also be utilized for treating soil/sand that was polluted by oil and chemicals in connection with waste dumps, leakage from oil pipes, and other process piping, accidents in connection with transport/tank plants, etc.

In connection with treatment of solid material to remove evaporizable matter, there is a specific requirement to separate the vaporizable substances in such a manner that they are not destructed or decomposed. Sale/reuse of the substances may be decisive to the economy of a process where solid material is treated to remove vaporizable matter. It is, thus, obviously desirable to be able to carry out such a thermal separation process at temperatures as low as possible, because much of the matter of interest might be destructed or decompose if subjected to temperatures commonly used to vaporize such matter.

The invention is based on utilization of the known steam distillation effect. Distillation with steam, as known, permits evaporation of matter, such as oil at a reduced vaporizing temperature.

From US-PS 4,139,462 utilization of the steam distillation effect in view of the heavier hydrocarbon fractions of oil is known, but this effect is only connected with water present in the raw material, i.e. cuttings, and it is, thus, dependent on the composition of the raw material before treatment. The stripping effect is achieved by water being converted into superheated vapor.

According to the invention a method as mentioned above is, thus, proposed which method is characterized by the fact that heating for vaporizing comprises heating in a heat exchanger which comprises a casing with a rotating, hollow rotor

provided in said casing. The material is conveyed during indirect heating from an inlet and to an outlet, said heating being carried out with a gradually increasing temperature profile in the direction of conveyance. Steam is injected into the material in a region of lower temperature in the heat exchanger, and exhaust vapor is removed from the heat exchanger and led to a condenser.

Examples of heat exchangers that may be utilized according to the invention, may be found in NO-PS 95 490, and NO-PS 122 742, which show and describe a conventional steam dryer, and a heat exchanger for indirect heating, drying, or cooling of more or less moist solid or semisolid material, respectively.

With such a method according to the invention a gentle heating profile of the material in the heat exchanger is achieved. The steam distillation effect is improved by heating with a gradually increasing temperature profile in the direction of conveyance, and with steam injection into the material in a region of lower temperature.

With the present invention, especially, an intended reproduction and control of steam distillation is achieved, independently of the composition of the raw material (especially its water content), but governed by molecular weight/structure of present hydrocarbon components. Superheating of the process steam is avoided or much reduced due to the fact that the relative water content of the material in the heat exchanger is increased by injection of steam, and consequently improved power consumption. Accordingly the total temperature of the gas mixture is reduced, which is advantageous, both as regards to specific heat, and the intended gentle treatment (value of reused oil).

Steam injection has several specific advantages.

Closely connected with reproduction/control of the steam distillation effect is the achievement of increased evaporation of hydrocarbons - especially heavier hydrocarbons and hydrocarbon components, i.e. a higher degree of separation/purity. The specific coefficient of heat transfer of the heat exchanger will be increased. The processing capacity of raw material for a given heating surface will, thus, increase considerably, without any reduction of separation efficiency or product quality. This increase is due to

- increased (longer) absolute contact time between heat surface and mass,
- improved convection properties,
- a higher degree of exchange of liquid around separate solid particles, thus, ensuring increased heat exchange,
- coating/fouling formed in the transition area between the wet and the dry phase which is preventing heat transfer, will be dissolved by the injected steam.
- improved flow and transport properties of the raw material (lumps are dissolved, air pockets collapse, etc.),
- direct steam injection itself provides improved agitation of the raw material.

At a given heating surface/solids temperature there will be variable steam content, in the total gas mixture different "equilibrium temperatures" will be formed. This will provide a more gentle separation (increased distance from the cracking-area for oils or oil components), and reduction of any unnecessary heating of the solid raw material. Totally, this will result in a better quality end product.

The relative ambient heat loss is reduced due to less difference in temperature between the process gas and ambient temperature.

Steam injection is preferably carried out in a region of 20-50% of the length of conveyance of the heat exchanger. Furthermore, a material filling of 60-90% of the volume of

the exchanger during heating in the exchanger have proved to be advantageous. Before heating, it may also be advantageous to have the material crushed. Especially by sorting out and mechanically crushing large particles, improved separation of raw material containing large particles and oil strongly bound by capillary action may be achieved.

If necessary, the material may be conditioned (heated) before it is introduced into the heat exchanger, and such conditioning may advantageously comprise addition of hot water to the material. Such controlled admixture of water to the material will result in improved "flow" properties and a certain control of the steam distillation effect.

Normally, treatment in the heat exchanger will occur under atmospheric pressure or a slight overpressure, but in certain cases the vaporizable matter may be of such a sensitive character that it may be suitable to work with an underpressure in the heat exchanger.

According to the invention the method may advantageously comprise compression of the exhaust gases from the heat exchanger, before the vapor goes to the condenser. In this connection compressed exhaust gas may with special advantage be led to an evaporator for indirect heat exchange and production of low pressure steam which is utilized as injection steam and/or as a heating medium for indirect heating in the heat exchanger.

According to the invention, the condenser may advantageously be used for heating conditioning water and/or feed water for production of steam for injection and/or hot water for indirect heating in the heat exchanger.

After the treated material, (solids) is removed from the heat exchanger according to the invention, water may advantageously be added in a discharge sluice. This will not only provide

for cooling of the processed material, but it will also provide superheated steam which will provide dynamic overpressure and pass in a counterflow to the material being discharged, into the heat exchanger, and out via the exhaust gas system. Thus, evaporated oil will be prevented from reaching the outlet to condense/leak out with the processed material. It is assumed that a certain stripping effect may also be achieved as regards to residual hydrocarbons in the material.

Additional supply of water in excess of the evaporating part will bind dust in the material. Treated material which is moistened by water may also provide improved sealing/flow properties as regards to formation of a desired plug of material in the sluice area.

Part of the treated material may be fed back from the outlet of the heat exchanger for mixture with inlet material to be processed. Such feedback will be especially advantageous when the material to be treated is of a specially moist/adherent kind. Such material requires that undesirable coating formed in the first section of the heat exchanger must be ripped up so that efficiency may be maintained. Feedback contributes to this effect because mixing dry material with the raw material will improve the physical properties of the feed material.

As mentioned one of the known continuous dryers may be used for a heat exchanger, with a casing having a rotatable hollow shaft or rotor, with supply of a heat carrier and removal of the same or a condensate of it, where the rotor carries hollow rotor blades, see the above mentioned Norwegian Specifications.

The invention is described in more detail with reference to the drawings, where

Figure 1 shows a flow sheet of a total process of which the method according to the invention may be a part,

Figure 2 is a graph showing residual oil in particles after indirect heating by heat transfer oil, as function of particle diameter, and residual oil in particles with a contribution of direct heating and steam distillation in addition (from steam injection),

Figure 3 is a graph showing how the boiling point is plotted as a function of percentage by weight of water in a mixture of water and oil,

Figure 4 is a graph with a temperature profile which is achieved by combined heating (preliminary heating from heat recovery, steam injection, and heat transfer by oil heating), and a less advantageous temperature profile in case of only heat transfer by oil heating,

Figure 5 is a flow sheet of a method according to the invention,

Figure 6 is a flow sheet of a variant of the process according to Figure 5, and

Figures 7-10 are flow sheets of different variants of processes with wich utilization of the method according to the invention.

Block diagram in Figure 1 shows a total process including the method according to the invention forming part of said process. Dependent on the kind of raw material all or some of the functions shown in the block diagram of Figure 1 will be used. Common to all kinds of raw material and, thus, central to the process is that a thermal separation is carried out, which may be carried out directly or after preliminary treatment and processing as shown in Figure 1. Commonly, drilling mud waste may, e.g. be homogenized/conditioned directly to be fed to thermal separation. The only preliminary treatment that might be of interest in this connection is classification of coarse/fine particles, and crushing/gri-

nding of the coarse particles before the portions are mixed (homogenized) and fed to thermal separation.

Treatment of other raw materials typically starts with rough sorting and removal of any junk, i.e. wood, large rocks, lumps of concrete, and steel/iron, before classification. This may be done manually, or by means of magnet and coarse screens. After said sorting out of foreign matter, the raw material is classified according to particle size/distribution, pollution and requirement of further treatment - e.g. by the use of shaking screens having varying wire clothes, etc.

In case of a raw material with strongly bonded capillary oil crushing of coarse particles will be necessary or advantageous to achieve satisfactory results.

In a normal processing sequence the raw material will either be subjected to washing or extraction, or it will be fed directly to the feeding tank of the thermal processor, where homogenization and conditioning by means of agitators, hot water injection, and indirect heating may be carried out before feeding to a processor (heat exchanger).

Conditioning which may, e.g. be carried out by means of hot water and/or idirect heating, is commonly used to achieve improved "flow" properties, but direct addition of hot water will also contribute to an increased steam distillation in the processor (and will, thus, reduce the need of steam injection in the processor). In connection with receipt/-treatment of frozen raw material which is to be directly separated thermally,preheating will be especially important.

Washing with water and/or extraction is preferably carried out with raw material containing water soluble chemicals, since oil based chemicals will follow the oil phase from the thermal processor to be separated from the oil in a simple

manner afterwards. Washing liquid is conventionally treated by means of precipitation, flocculation, filtration, and the like after washing, and the respective chemicals may then be destroyed or used in their respective actual amounts.

After washing/extraction the raw material may, if special conditions may require this, be returned to classification and may possibly be subjected to full or partial grinding of large particles before supply for homogenization /conditioning and supply to thermal separation.

After satisfactory/selected homogenization and conditioning the raw material is fed to a rotating heat exchanger, known from other contexts, where mainly indirect heating of the raw material occurs with subsequent evaporation of the liquid content.

Dependent on the raw material, specific liquid conditions/contents, specific capacity, and the degree of capillar/adhesion bound oil, the necessary separation temperature of the raw material will vary from just above 100°C to just below 300°C. This order of temperature is achieved by indirect heating, mainly by the rotor of the heat exchanger (in some instances heat supply to the stator will also be advantageous). The heat transfer medium normally used for temperatures of the material above 100°C to 180°C is saturated steam, and for temperatures above 180°C to 300°C heat transfer oil is used (heat transfer oil may, if desired, be used over the whole range of temperatures).

Normally, the heat exchanger or processor operates at a slight atmospheric overpressure (5-40 millibar). In this manner any seeping in of oxygen (air) is avoided and self drive of exhaust gas is achieved. In certain cases it will, however, be sensible to use subpressure in order to enhance evaporation still more (lower the boiling point curve of the mixture), or more gentle separation, due to the fact that the

temperature of the material may, thus, be reduced. The lowest operating pressure of the heat exchanger will normally be 0.1 bar absolute. In this pressure area (0.1-1.1 bar a) only simple measures in the form of redesigned inlet and outlet sluices, and a vacuum pump/liquid seal downstream of the condenser, will be required.

The exhaust gases (i.e. mainly water and oil) are conducted from the thermal processor to indirect condensation and subcooling, and subsequent precipitation/separation. Non-condensable substances passing through the condenser (e.g. decomposed chemical substances from drilling mud, and to some extent cracked hydrocarbons) are conducted to a heat transfer oil or steam boiler where complete combustion and conversion of gas energy occurs. This destruction by combustion may functionally be combined with the main burner of the boiler in one and the same function. Alternatively, the gases are conducted to absorption in an active carbon filter.

After conventional separation further treatment of the liquid phases may be carried out, e.g. in connection with purification equipment associated with the washing process.

Discharged water from the process will contain maximum 30 ppm hydrocarbons/compounds as an upper limit.

Discharged non-volatiles (solid phase) from the processor may be transported, by means of compressed air, to a conventional bulk bunker. Said bunker may be designed with double walls for cooling/heat recovery from the non-volatiles. If it is desirable to return the non-volatiles, e.g. from polluted soil, in the form of useful soil, such cultivation may be carried out in connection with the processing plant.

Non-volatiles discharged from the processor will commonly contain less than 1 % by weight of hydrocarbon residues.

Biological after-treatment - forming part of a complete plant - may be carried out to provide a finished/composted product which will be useful as satisfactory soil after a certain ripening time after deposition.

Crushing and grinding of a mass may be carried out after the washing/extraction proceses, or directly if the mass is not washed/extracted. The object of such crushing/grinding is described below, with reference to Figure 2. Particles that have been subjected to oil under high pressures (e.g. reservoir-conditions), will show a relatively high degree of oil-filling of the pores. Removal of oil from these particles will have a reduced effect inwards, towards the core, because heat conduction is poor and the transport distance of oil out of the particles is long. Residual oil in particles as a function of particle size is qualitatively shown in Figure 2. A full line indicates residual oil in particles in case of indirect heating with heat transfer oil, as a function of particle diameter. A corresponding curve in a dashed line indicates conditions with contribution of direct heating (by steam injection).

Crushing/grinding is recommended for coarse drilling mud waste, but is regarded as less required for soil which contains oil, and the like. The utilization of the steam distillation effect (stripping effect) is, as mentioned, central in the present invention. Injection of steam and water being present in the raw material will cause a decrease of the boiling point of the whole system (oil + water). This is illustrated by the graph of Figure 3.

The shape of the curve of boiling point is caused by the fact that accumulations of water molecules which are evaporated (from 100^{o}C upwards) will carry oil molecules due to the attractive forces acting between water molecules and oil molecules (Van der Waal effect).

In this connection utilization of the steam distillation principle has two effects. Said utilization secures gentle processing (moderate temperatures) with limited destruction of the raw material, and also improved heat transfer properties.

The most important advantages of direct steam injection may be summed up as follows:

Increased volumes of water provide increased oil evaporation from each particle due to an increased washout effect, and reproduced washing out in the heat exchanger. Improved heat transfer properties due to an increased content of liquid and contribution by direct heat transfer from condensing vapor. Hot water/vapor will more readily strip off capillary bound and surface bound oil from the mass.

Increased liquid content will make the matter more mixable and provide improved distribution of transferred heat in the entire mass.

It should be mentioned here that by processing at maximum temperatures of 180-300°C the probability of cracking will be low, but small amounts of light hydrocarbons may be formed. They may, however, be destroyed in the combustion chamber of the heat transfer loop in the plant.

Possible manners of carrying out the method according to the invention will now be described in more detail with reference to Figures 5-10, which show various processing concepts of the method according to the invention.

Thermal separation, as mentioned, is a central aspect of the invention. From previous preliminary processing two factors will be of special importance to the thermal phase:
a) any reduction of particle size (crushing)
b) water content (from washing and/or conditioning).

Said factors will directly influence thermal processing, i.e. as regards to the volume of steam to be injected, residence time, heating profile, and to a certain degree separation efficiency/operating temperature.

Superior parameters of thermal processing are:
- continuous processing
- stable capacity (independent of type of raw material)
- stable, efficient separation (e.g. less than 1% of hydrocarbons in non-volatiles),
- high reuse value of the separation products (gentle treatment).

This is directly achieved, to a high degree, in the said heat exchanger (processor) due to its especially advantageous structural design for this purpose, and due to direct utilization and control of the steam distillation effect, and the specially favourable heating profiles which may be achieved in the first section of the processor.

In Figure 5 a processor 1 is shown. This is a heat exchanger comprising a casing 2 with a rotor 3 provided in said casing. Rotor 3 mainly consists of a hollow rotor shaft 4 on which a number of hollow rotor discs 5 are attached. The internal space of the rotor discs 5 is directly connected to the hollow space in the rotor shaft 4. Paddlers (not shown) or the like are mounted on the rotor discs, in order to cause material conveyance through the heat exchanger, from the left to the right hand side in the figure. Processor 1 has an inlet 6, and an outlet 7. There is also provided an exhaust gas outlet 8 from casing 2.

Inlet 6 is supplied with material to be treated from a conditioning tank 9. Exhaust gas outlet 8 is connected by a pipe 10 with an indirect condenser 11. Outlet 7 is connected with a discharge sluice 13, via a duct 12.

The hollow rotor shaft 4 is fed with steam from a boiler 14, via pipe a 15.

The previously described conventional heat exchanger is modified by a mounted steam injection means 16. This may be of several practical designs which will be familiar to those skilled in the Art. It may, e.g. be a question of several nozzles provided in the shell of casing 2 and connected with a common manifold attached by welding, so that steam may be injected directly into the material which is in the dryer. Steam is supplied through a piping 17 from piping 15 from boiler 14.

The material to be processed is supplied to a sorter 19, as indicated by arrow 18. Coarse material is supplied to a crusher 20 and then to supply and conditioning tank 9. Fine material goes directly to tank 9, as shown. If necessary, tank 9 is also provided with non-volatiles from discharge duct 12, via piping 21. From the supply and conditioning tank the conditioned material passes on to inlet 6 of the heat exchanger, as indicated by arrow 22.

Hot water for conditioning is fed to the material in tank 9 through piping 23 from condenser 11, the cold water feed of which is shown at 24.

The exhaust gas formed during processing in processor 1 passes out through exhaust-outlet 8 and to condenser 11 through a pipe 10. The condensate is discharged through pipe 25.

The treated material, also called non-volatiles in this context, is removed from outlet 7 and passes through duct 12 to outlet sluice 13. A conveyor screw 26 in sluice 13 feeds non-volatiles to a discharge zone 27. In a water supply zone 28 water from condenser 11 is supplied through pipe 23 and

branch piping 31. Water supply here will result in formation of steam which will provide a dynamic overpressure and pass in counterflow relative to the non-volatiles, back to processor 1, as shown by dashed arrow 29. This will prevent evaporated oil from passing with non-volatiles through overflow 30 in the heat exchanger to condense on or leak out with the non-volatiles. A certain stripping effect may also be achieved as regards hydrocarbons in the non-volatiles.

Supply of water in excess of what will evaporate will bind dust in the non-volatiles, and increase or provide moisture which will cause a certain "lubricating" effect in conveyer screw 26. Binding dust will mean a considerably simplified further transport of the finished product.

Water supply in the sluice will also cause cooling of the product.

In the sluice a "plug" of material is desired. Formation and control of such a plug in discharge zone 27 is simplified when non-volatiles are moistured by water, because the material will acquire improved sealing/flow properties.

Although not tested, it is assumed that it will be possible to return all condensed and separated process water to the finished product and, thus, avoid all requirements as regards to discharge water.

The plant of Figure 6 substantially corresponds to the plant shown in Figure 5. The processing plant is modified in relation to what is shown in Figure 5. Thus, a heat transfer oil boiler 32 is used for heating of processor 1, and for steam production in a steam generator 33. Sluice 13 and generator 33 receive a water supply from condenser 11 through piping 34, 35. Generator 33 delivers steam to injector means 16 through a pipe 36. Components which corresponds to those of Figure 5 are designated by the same reference numerals.

The plants of Figure 5 and 6 operate with a working temperature up to 180°C, with saturated steam as an indirect heating medium. The temperature of steam in pipe 15 is between 120°C and 180°C at a pressure of 2-10 bar g.

Corresponding working conditions prevail in the plant shown in Figure 7. This plant is, in principle designed in the same manner as the plant of Figure 5, but the hollow rotor 4 is divided in this case, by being provided with an internal partition 37. Such a bipartite rotor-design contributes to a very gentle heating profile and heat recovery. It should be mentioned in this connection that the stator, i.e. casing 2, may also be designed as a heat transferring surface, and that the stator may, thus, be divided in the same manner as the rotor.

Hot water from condenser 11 is in Figure 7 fed through a pipe 38 towards the partition point of the rotor (if desired, of the stator as well), i.e. partition 37, to flow in a counterflow to the incoming raw mateial, and out through conduit 39. Indirect condensator 11 operates in such a manner that discharged hot water will have a highest possible temperature (before flowing into processor 1) without exhaust gases passing through the condenser (apart from non-condensable substances). From pipe 39 a pipe 41 branches off to tank 9.

Steam is supplied from boiler 14 through a pipe 15 to the rotor 4 and to steam injection means 40, which is here displaced as compared to the arrangement of Figures 5 and 6, so that steam injection into the mass in processor 1 will occur approximately at partition 37. In the hollow rotor shaft 4 the steam will flow towards partition 37 and back, on the other side of a longitudinal partition in hollow rotor 4, and back to the boiler. For the remaining components of the

plant which are also to be found in Figures 5 and 6 the same reference numerals are used.

Such bipartite heating (bipartite rotor and, if desired, stator), combined with the direct heating from injected steam at the transition between the two indirect heating zones, will provide gentle (stepped) heating of the material in the heat exchanger.

The plant shown in Figure 8 comprises a sorter 19, a crusher 20, a supply and conditioning tank 9, and a condenser, as well as a discharge sluice 13, as does the plant shown in Figures 5-7, but processor (heat exchanger) 1 is of the modified kind, as shown in Figure 7, i.e. with a divided rotor (partition 37). In the same manner as in Figure 6, a heat transfer oil boiler 32 with an associated steam generator 33 is used, but the heat transfer oil in the present case passes through a pipe 42 to the right hand side of partition 37, whereas the left hand side portion of rotor 4 is connected with the condenser, via a pipe 43.

Vapor to the injector means shown in Figure 7 passes through a pipe 44 from vapor generator 33. Heating water used in rotor 4 flows to tank 9, sluice 13, and generator 33 through the shown piping 45, 46, and 47.

The plant shown in Figure 9, like the plants discussed above, comprises a sorter 19, a crusher 20, a feed and conditioning tank 9, a condenser 11, and a sluice 13. Processor 1 is of the kind as shown in Figures 7 and 8, i.e. divided (partition 37 in rotor 4), and a boiler 14 is used, like in Figures 5 and 7.

In the plant shown in Figure 9, exhaust gas passing from processor 1, through gas outlet 8, is compressed in a compressor 48. Compressed exhaust gas flows to an evaporator 49 and then thrugh pipe 50 to condenser 11. The condenser is

in this case used for subcooling the condensate from the evaporator. Cooling water from condenser 11 flows through piping 51, 52 to the evaporator, and on to tank 9, and sluice 13, respectively, through piping 53 and 54.

Low pressure steam is formed in evaporator 49, and flows through a pipe 55 to the left hand side portion of the divided rotor 4 in order to heat said rotor portion, and will return through pipe 56. Low pressure steam is also used as an injection medium in steam injector means 40 (through pipe branch 57).

The plant shown in Figure 10 only differs from the plant according to Figure 9 by having steam boiler 14 exchanged with a heat transfer oil boiler 58. The right hand side rotor portion is thus heated by heat transfer oil, via piping 59, 60.

Heat transfer oil will have a temperature in the region of 180-320°C.

Whereas maximum processing temperature reaches 180°C in plants comprising a steam boiler, maximum processing temperature will reach approximately 300°C in plants with a heat transfer oil boiler.

The plants shown in Figures 9 and 10 are developed for optimum utilization of energy.

Even though the concepts shown in Figures 9 and 10 represent approaches requiring a certain increase in investments in addition to the necessary basis for carrying out the invention, it will be possible to achieve a considerable energy economical benefit (approximately 50-70% as compared to the more conventional concept of Figures 5 and 6). The optimal concepts shown in Figures 9 and 10 introduce utilization of a compressor, where exhaust gas from the gas

outlet (the gas commonly has atmospheric pressure) is compressed up to a maximum of 2 bar absolutely. Further compression would not be profitable, nor would it be suitable as regards the gas quality for reuse as a condensate (oil phase). This moderate compression is mainly utilized to raise the condensation temperature of the water content of the gas (where the largest amount of energy is "stored"), so that it is possible to exchange it at a higher "level" against: water to steam. In this manner a heating medium results, which may be exchanged with the first portion of the rotor (to the left hand side of the partition, if desired a corresponding portion of the first part of the stator), and which contains more energy at a higher "level" and, in turn supplies incoming raw material with more heat advantageous to the heat suply by steam or heat transfer oil boiler. The advantageous heating profile (which will be explained in more detail below) and use of steam injection will be as disclosed above. When saturated steam is generated to serve as a heat exchanging medium in the evaporator, injection steam will also be taken for the process from here - slightly conditional on the arrangement of nozzles in the steam injection means and the kind of raw material - advantageous to the steam boiler/steam generator in the respective concepts. The total utilization of generated steam from the evaporator to the first portion of the rotor (possible stator) and for direct injection, thus, provides an energy benefit of 50-70% as compared to the more conventional concept.

The most optimal approach as regards energy consumption is, thus, compression of exhaust gas and indirect heat exchange against water which is converted to saturated steam, especially because of the fact that this steam is used both for indirect heating in the first portion of the rotor (stator), possibly in a conditioning tank before the processor, and for direct injection (reproduction/control of the stripping). The energy cycle then forms an approximately closed circle (if losses are disregarded), and both process-

ing result and energy consumption are optimal, at the same time as the injected volume may be varied/increased over a much larger region, and solely determined by the demands of the raw material/separation process.

In carrying out the new method, steam with a temperature of 115-180°C is injected into the heat exchanger by a steam injector. The longitudinal section of the heat exchanger covered by the injector, e.g. comprises 30% of the length of the heat exchanger and is divided into sections by the use of valves controlling the volume supplied to each section. Such sectioning of steam injection may be of interest both in the longitudinal and transversal profile of the processor. Distribution of injected volumes to the sections is adapted so as to achieve a temperature profile with a moderately rising gradient in the longitudinal direction.

Too rapid temperature increase will drive out water before the specific effects of the water are utilized.

High temperatures in the first part of the heat exchanger will, furthermore, result in a disproportionally high loss of energy to superheating of the steam in the heat exchanger.

A desired temperature profile is diagrammatically shown in Figure 4. This figures shows a full line representing the temperature profile for combined heating (preliminary heating, steam injection, and heat transfer oil heating). The dashed line represents the temperature profile of conventional heating, see Figures 5 and 6.

The special selection of processor (heat exchanger) will be attached to the following effects:
- A large heating surface of the rotor,
- good posibilities of different heating media in various parts of the rotor,
- a well mixed mixture which improves heat transfer,

- a controlled degree of filling.

A suitable degree of mass filling will be 60-90% of the volume available in such a heat exchanger. The residual volume is used by evaporated oil and water, passing to the exhaust gas outlet, which will be favourable to evaporation.

In a rotating heat exchanger with a single direction of rotation, the material will be continuously rolled and form a sliding face in transverse section. This means that the material is unevenly distributed in cross section. To compensate for this steam injection may, thus, advantageously be controlled across a transverse sectional portion. In the diagrammatic Figures a series of nozzles is shown in the longitudinal direction of the heat exchanger. Correspondingly, nozzles may be provided side by side transversally (normally on the plane of the Figure). Also, a pattern of nozzles is used with nozzles placed in rows and columns. By the use of such a pattern of nozzles or a similar pattern injection may be controlled both in transverse section and longitudinal section of the heat exchanger. Control in the longitudinal section may be advantageous to compensate for the fact that the water content is relatively high in an initial phase, whereas it will decrease gradually. It may, thus, be necessary to supplement the water content, added by steam injection. Such a controlled injection profile is determined by the operating conditions.

CLAIMS:

1.
A method in treating solid material to remove vaporizable matter, comprising a thermal separation process, where the solid material is subjected to heating and steam distillation to vaporize substances to be removed from the material, especially to remove hydrocarbons from cuttings, polluted soil, etc., c h a r a c t e r i z e d i n that heating for vaporation comprises heating in a heat exchanger, which comprises a casing with a rotating hollow rotor inside said casing, and wherein material is conveyed while being indirectly heated, from an inlet to an outlet, said heating being carried out with a rising temperature profile in the direction of conveyance, that steam is directly injected into the material at a region of lower temperature in the heat exchanger, and that the exhaust gas is removed from the heat exchanger and conducted to a condensator.

2.
A method according to claim 1, c h a r a c t e r i z e d i n that steam injection is, preferably, carried out in a region of 20-50% of the section of conveyance of the heat exchanger.

3.
A method according to claim 1 or 2, c h a r a c t e r - i z e d i n that heating in the heat exchanger is carried out with a material filling of 60-90% of the volume of the heat exchanger.

4.
A method according to one of the preceding claims, c h a r a c t e r i z e d i n that the material is crushed before being heated.

5.
A method according to one of the preceding claims, c h a r a c t e r i z e d i n that the material is conditioned (temperature and water content) before being introduced into the heat exchanger.

6.
A method according to claim 5, c h a r a c t e r i z e d i n that conditioning comprises supply of hot water to the material.

7.
A method according to one of the preceding claims, c h a r a c t e r i z e d i n that the material is kept below atmospheric pressure in the heat exchanger.

8.
A method according to one of the preceding claims, c h a r a c t e r i z e d i n that the exhaust gas from the heat exchanger is compressed and led to a condenser.

9.
A method according to claim 8, c h a r a c t e r i z e d i n that compressed exhaust gas is led to an evaporator for indirect heat exchange and production of low pressure steam which is utilized as injected steam and/or as a heating medium for indirect heating in the heat exchanger.

10.
A method according to one of the preceding claims, c h a r a c t e r i z e d i n that the condenser is utilized for heating of conditioning water and/or feed water for production of steam to be injected and/or used as hot water for indirect heating in the heat exchanger.

11.

A method according to one of the preceding claims, c h a r a c t e r i z e d i n that the treated material is added water in a discharge sluice after discharge from the heat exchanger.

12.

A method according to one of the preceding claims, c h a r a c t e r i z e d i n that part of the treated material from the outlet of the heat exchanger is fed back to be mixed with material to be treated.

13.

A method according to one of the preceding claims, c h a r a c t e r i z e d i n that steam injection is varied along the longitudinal section and transverse section of the heat exchanger in order to achieve a controlled injection profile.

Fig. 1.

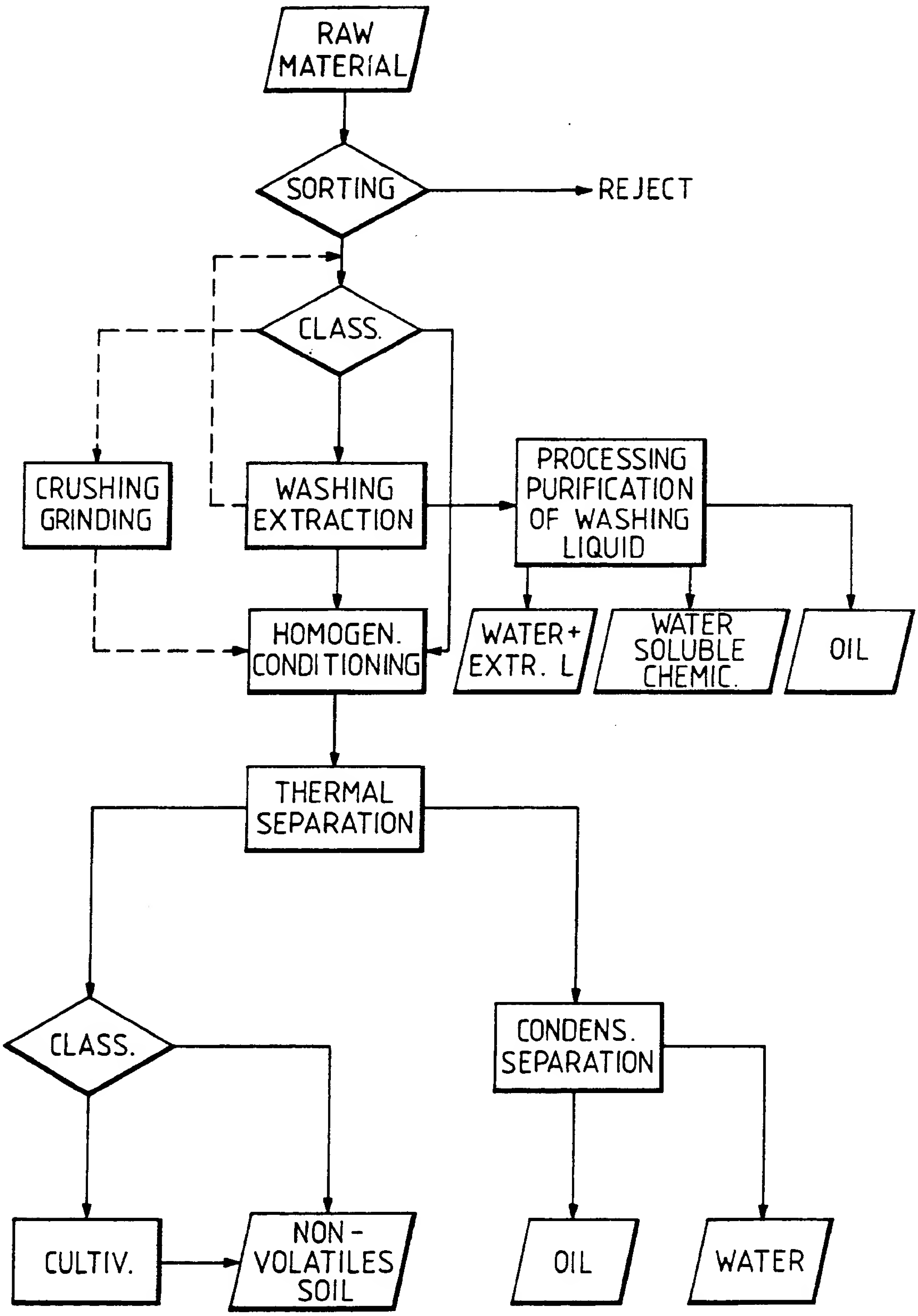

RAW MATERIAL
SORTING
REJECT
CLASS.
CRUSHING GRINDING
WASHING EXTRACTION
PROCESSING PURIFICATION OF WASHING LIQUID
HOMOGEN. CONDITIONING
WATER + EXTR. L
WATER SOLUBLE CHEMIC.
OIL
THERMAL SEPARATION
CLASS.
CONDENS. SEPARATION
CULTIV.
NON-VOLATILES SOIL
OIL
WATER

Fig.2.

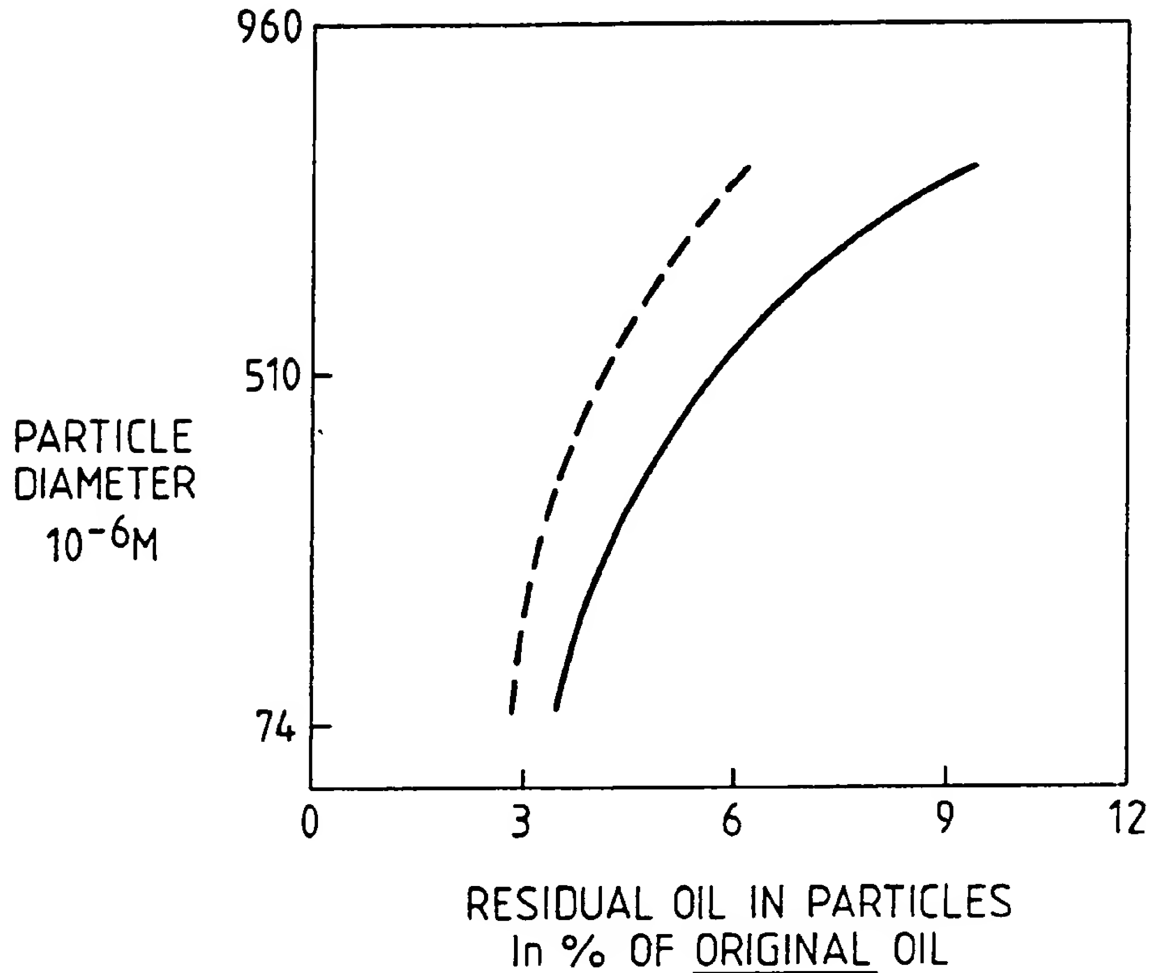

960
510
74
PARTICLE
DIAMETER
10^{-6}M
0
3
6
9
12
RESIDUAL OIL IN PARTICLES
In % OF ORIGINAL OIL

Fig.3.

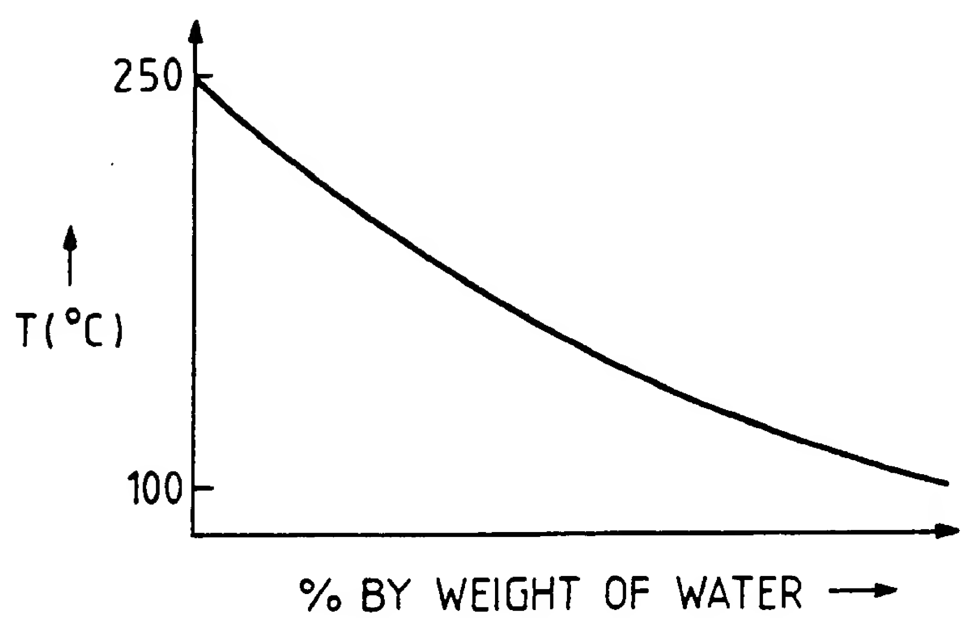

250
T(°C)
100
% BY WEIGHT OF WATER

Fig.4.

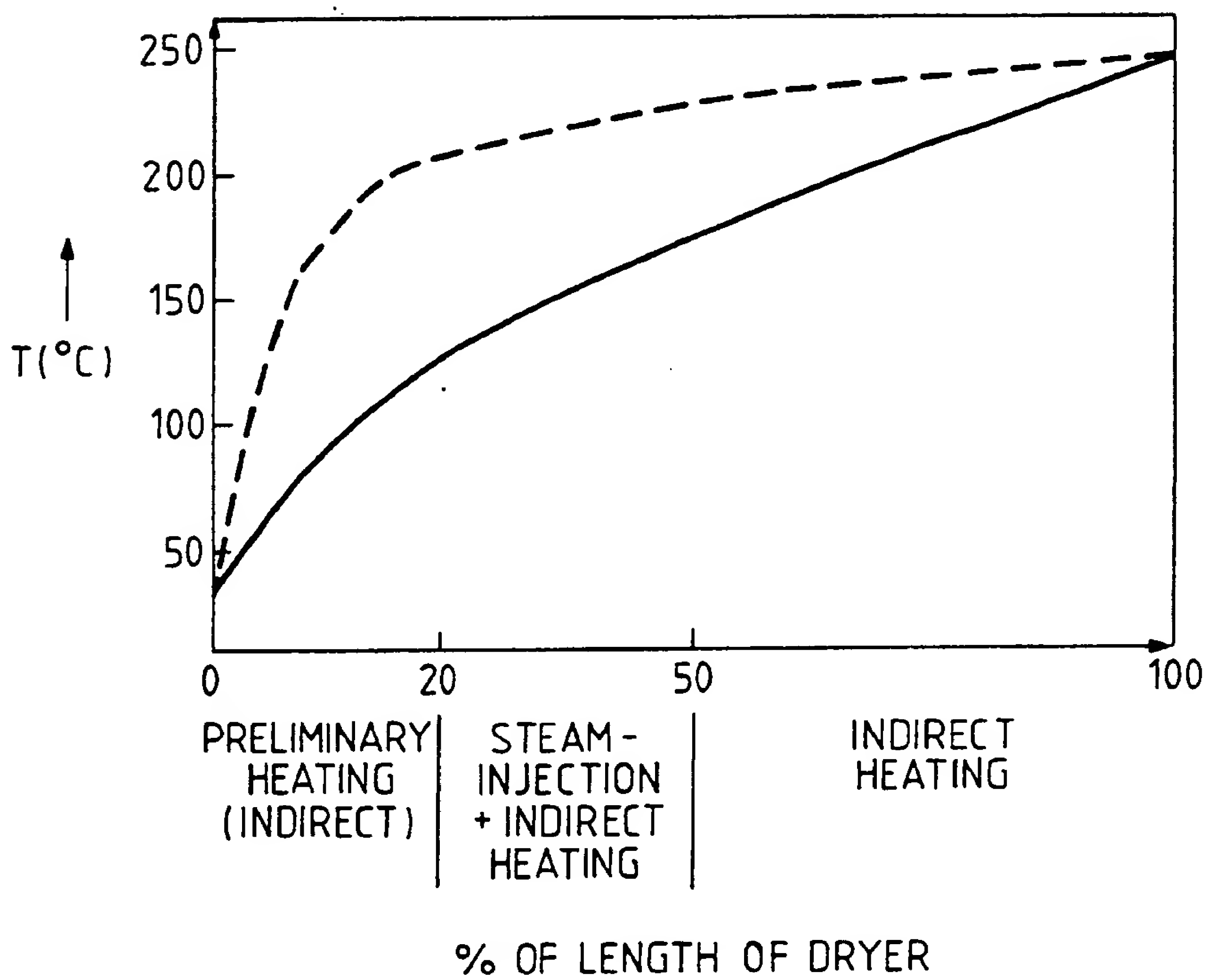
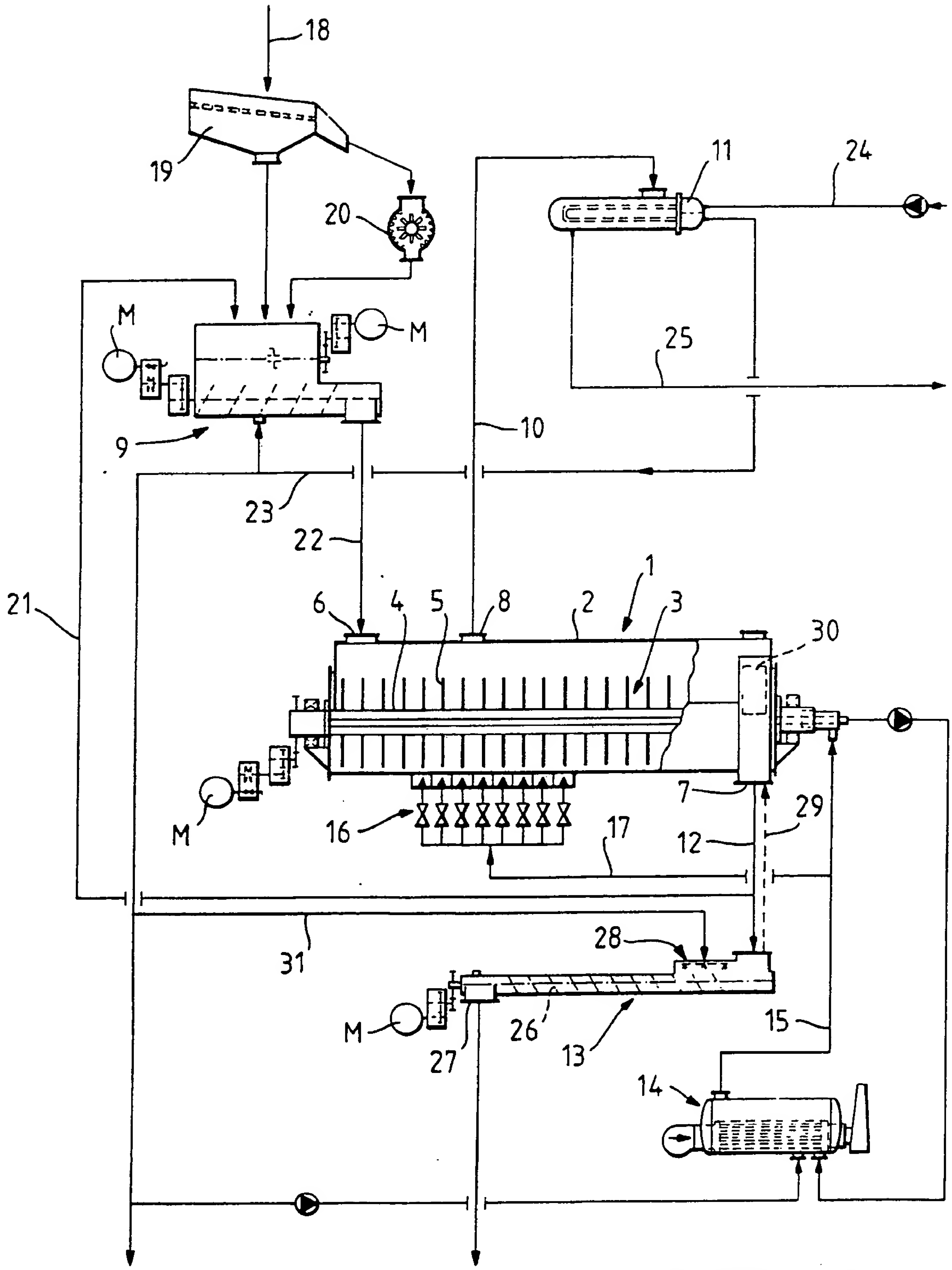

250
200
150
100
50
T(°C)
0
20
50
100
PRELIMINARY HEATING (INDIRECT)
STEAM-INJECTION + INDIRECT HEATING
INDIRECT HEATING
% OF LENGTH OF DRYER

Fig. 5.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19
20
11
24
25
10
M
M
9
23
22
21
6
4
5
8
2
1
3
30
M
16
7
17
12
29
31
28
M
26
13
27
15
14

Fig.6.

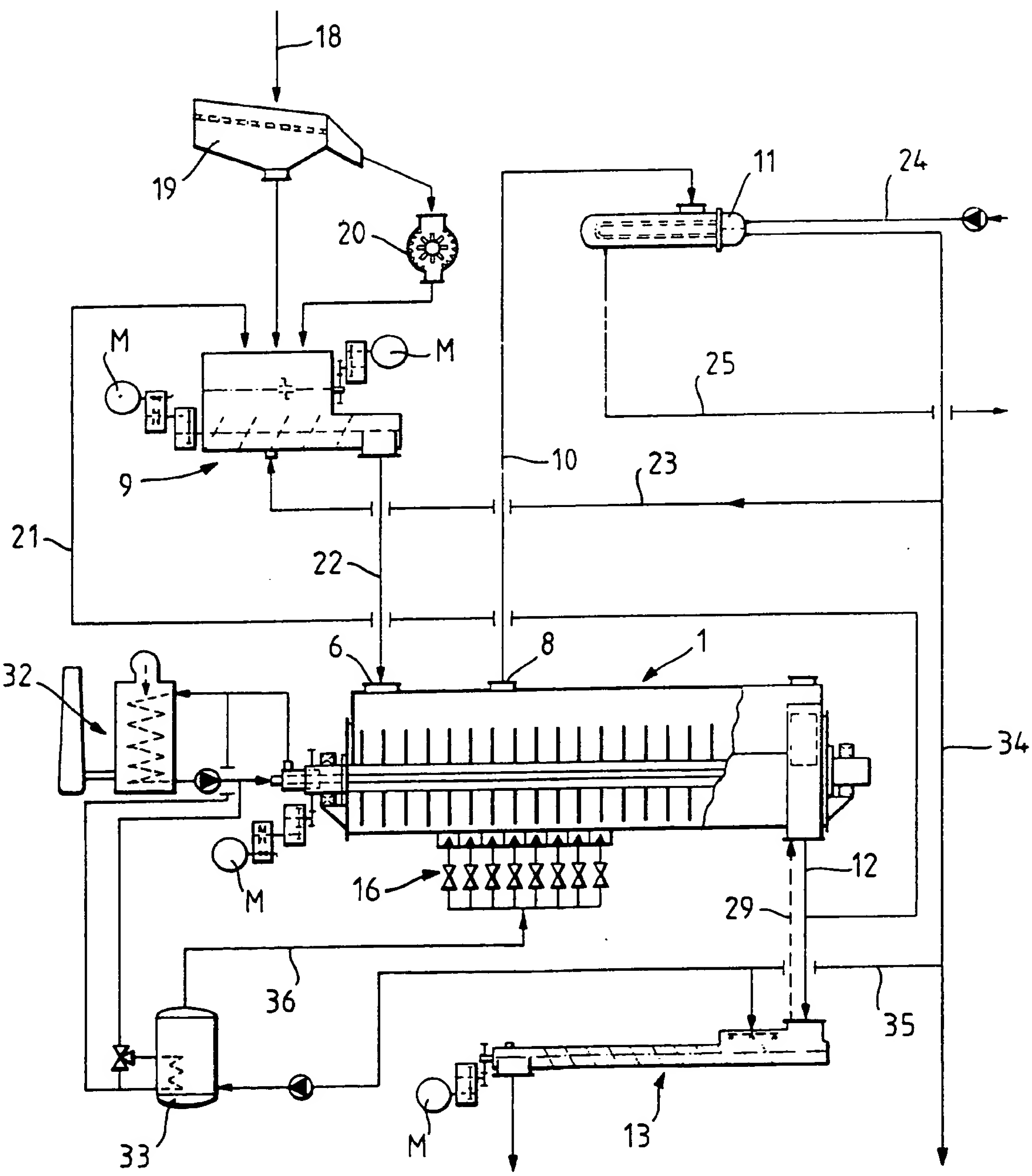
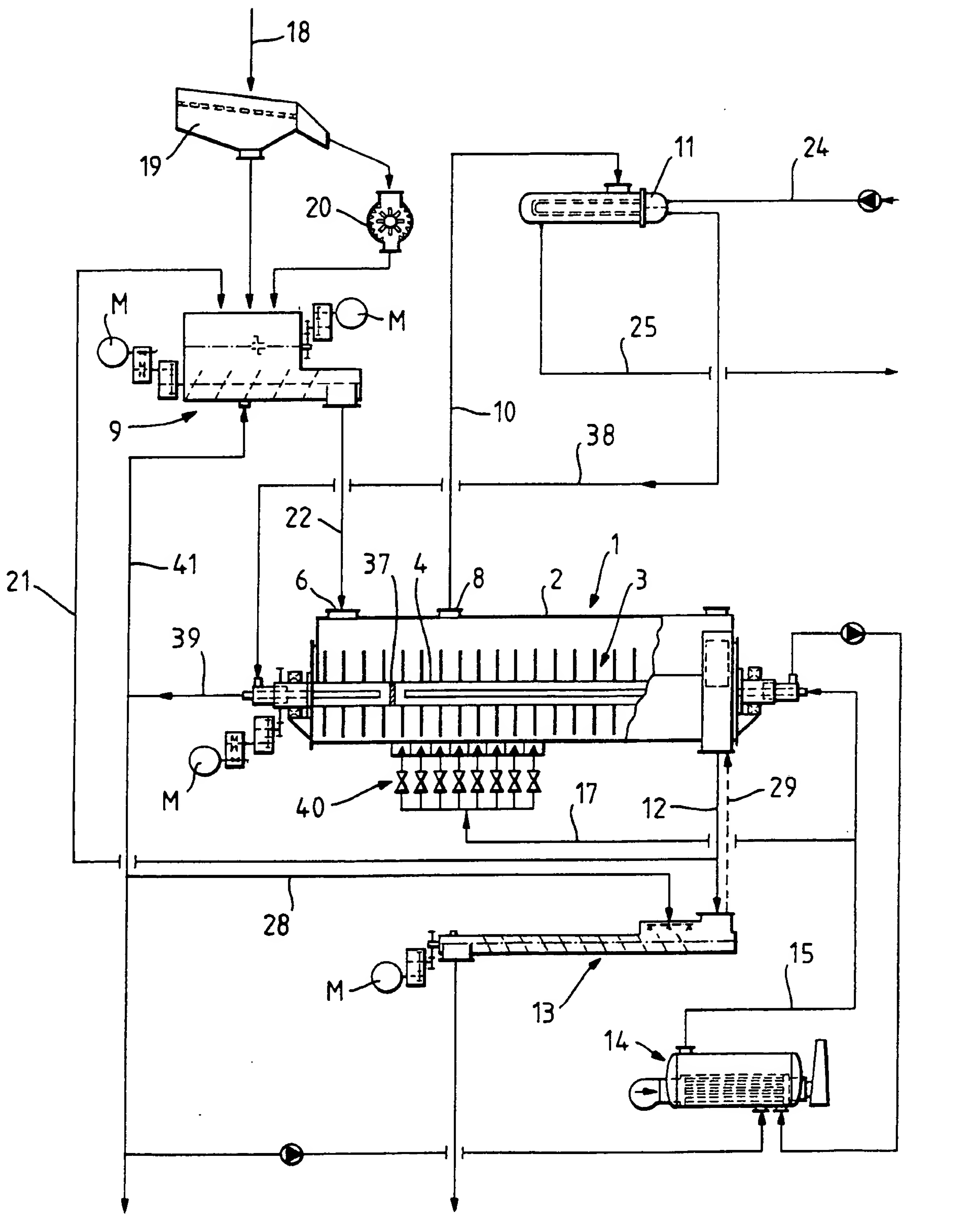


Fig. 7.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M
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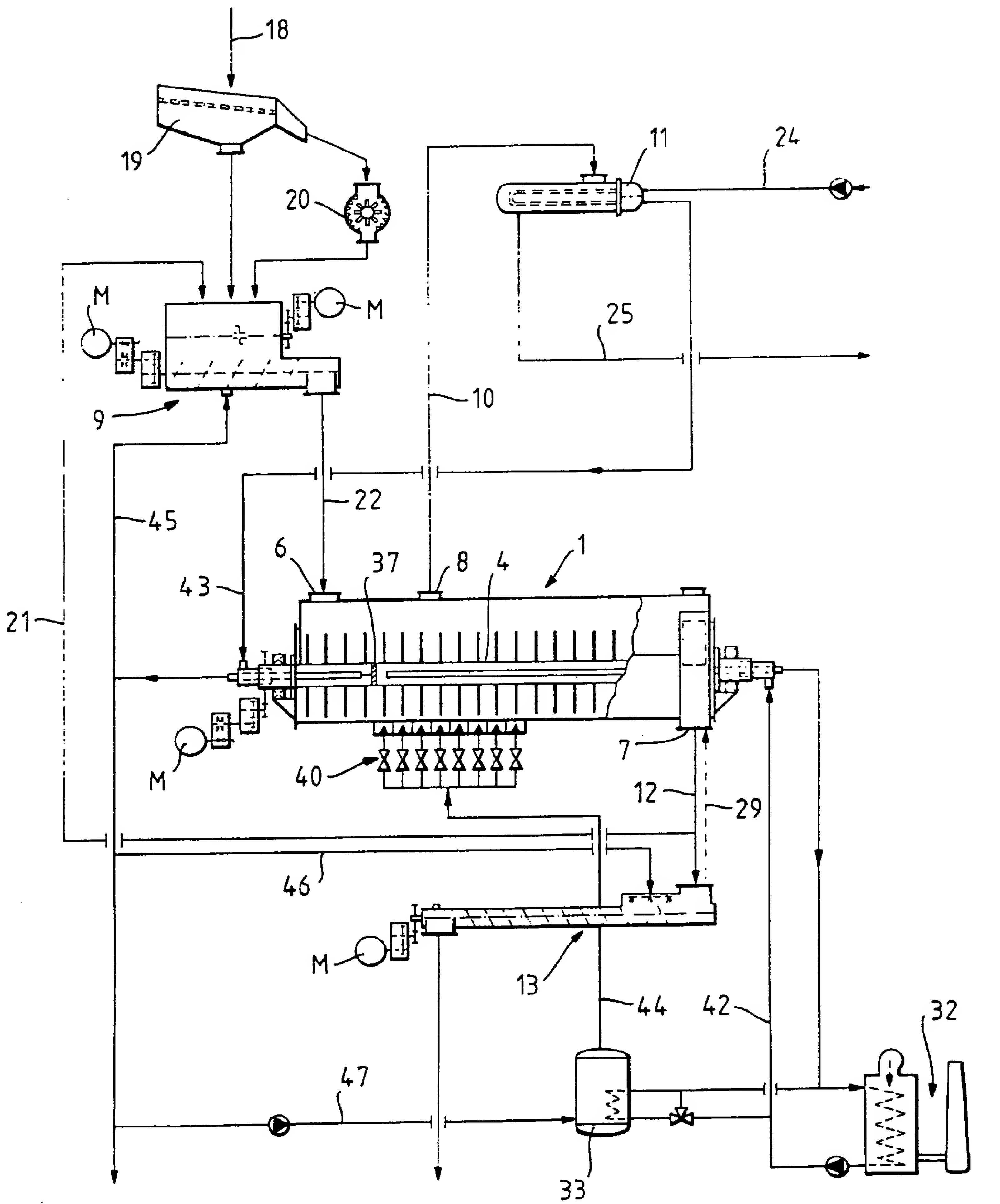
10
38
22
41
21
1
37
4
6
8
2
3
39
M
40
17
12
29
28
13
M
15
14

Fig.8.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M
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45
1
6
37
8
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43
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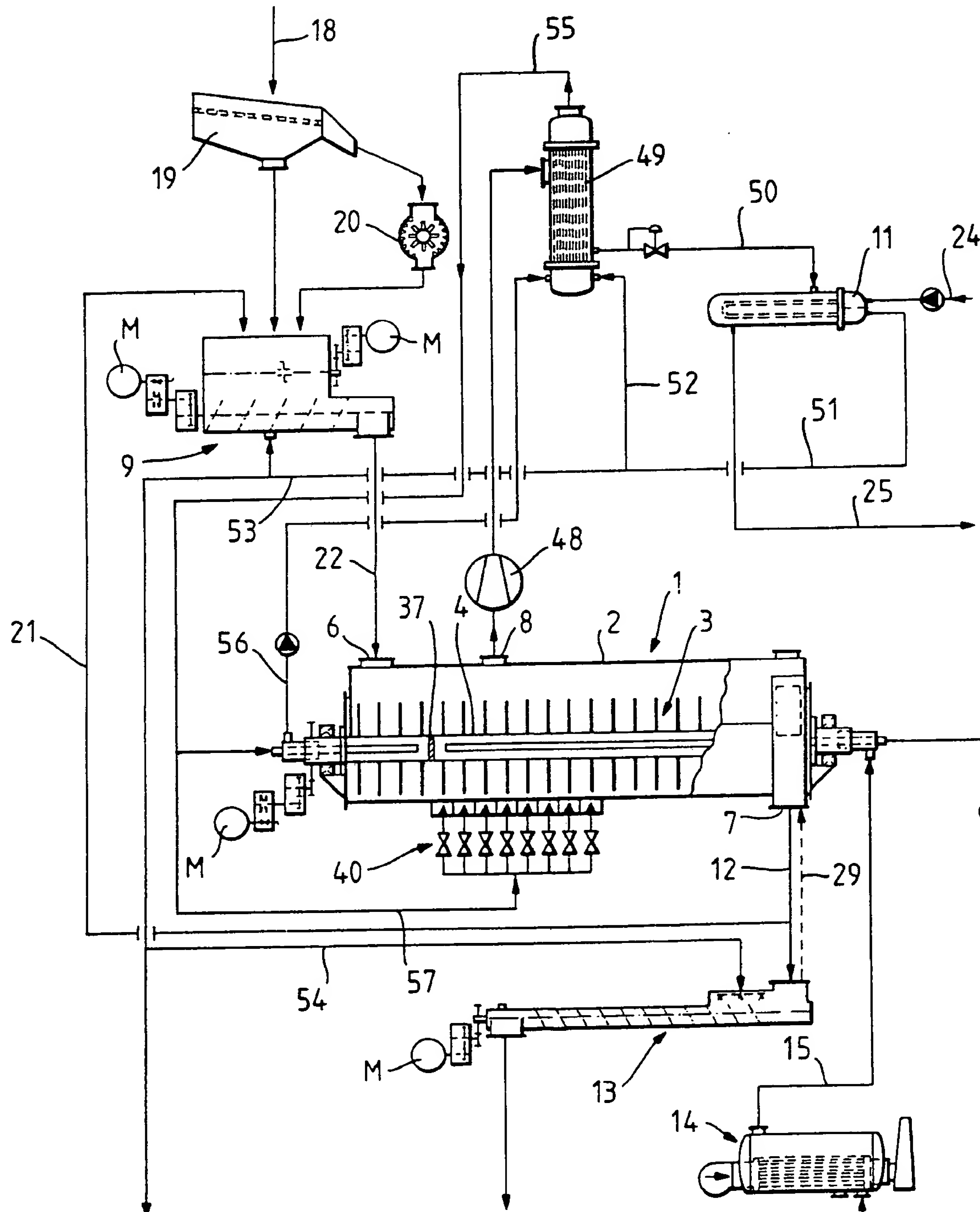
M
7
40
12
29
46
M
13
44
42
32
47
33

Fig. 9.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M
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9
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22
21
37
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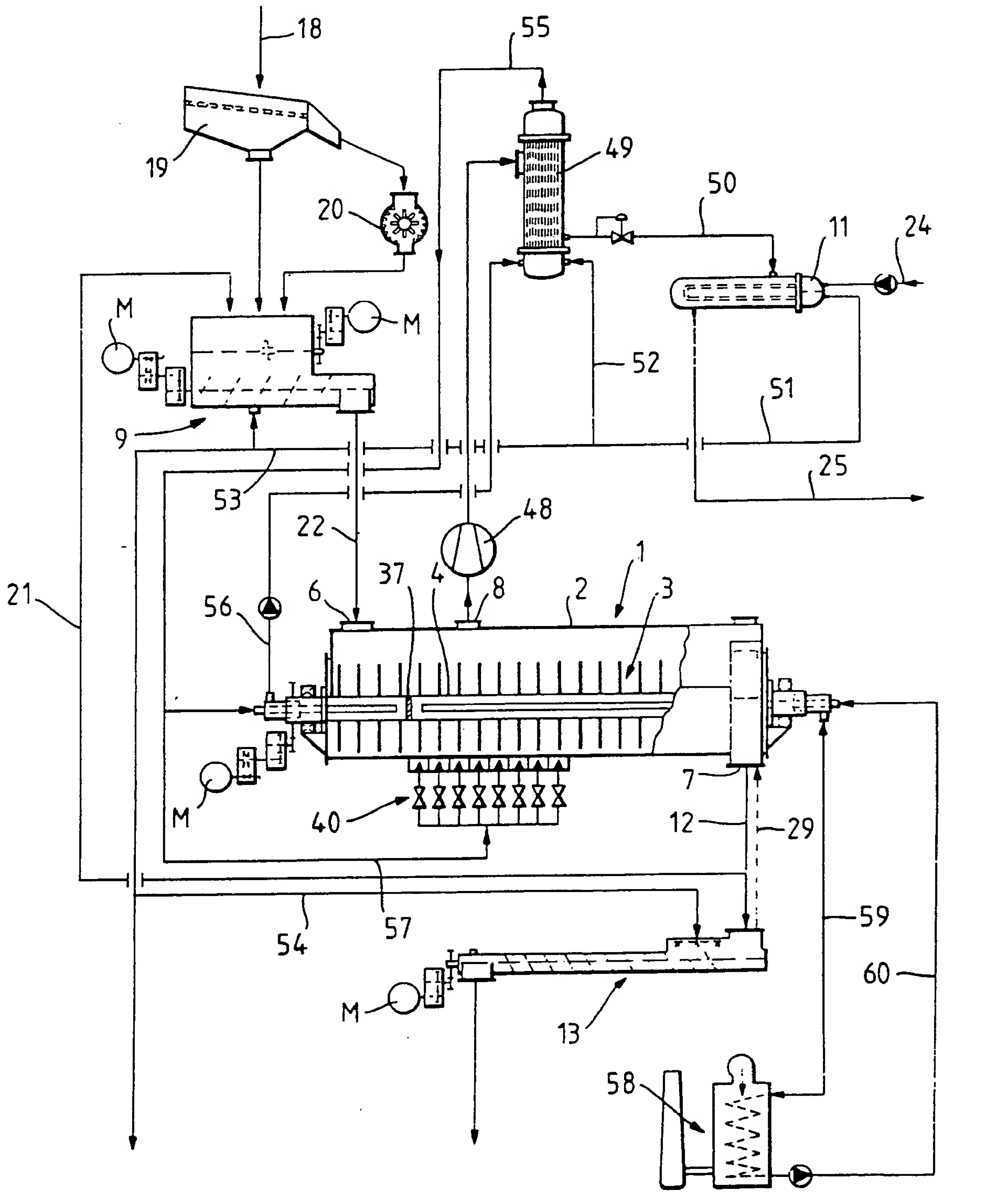
8
2
1
3
56
6
7
M
40
12
29
57
54
M
13
15
14

Fig. 10.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6
8
2
3
M
40
7
12
29
57
59
54
60
M
13
58

INTERNATIONAL SEARCH REPORT

International Application No PCT/NO89/00032

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [8]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

B 01 D 1/18, 3/28, F 26 B 3/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 4	B 01 D 1/00, 1/14-1/18, 3/28 F 26 B 3/00-3/16, 11/02-11/06, 11/18-11/20, 17/30-17/34
US Cl	34: 108, 126-142; 203: 90, 95-97

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	NO, B, 154 945 (RAFFAELE RAGAZZON) 13 October 1986 See figure 1 and page 3	1-3
Y	GB, B, 1 142 155 (INSTYTUT PRZEMYSLU SZKLA I CERAMIKI) 5 February 1969 See page 2, lines 1-10 & NL, 6602279 BE, 676916 DE, 1604943	1-3
A	CH, A, 536 990 (BAKER PERKINS INC.) 29 June 1973	1-3
A	EP, A1, 0 063 486 (DIN ENGINEERING LIMITED) 27 October 1982	1-3
A	DE, A1, 3 107 407 (CARL STILL GMBH & CO KG) 22 April 1982	1-3

.../...

* Special categories of cited documents: [10]
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1989-07-11	1989 -07- 17
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Bengt Christensson

International Application No. PCT/N089/00032

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	WO, A1, 84/01207 (E.G. KRONELD) 29 March 1984	1-3, 8
A	US, A, 4 222 988 (HORST K.F. BARTHEL) 16 September 1980	1-3

Form PCT/ISA/210 (extra sheet) (January 1985)